Analysis Of Defect Reduction Using The Six Sigma Method In A Fertilizer Factory In Gresik Regency

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A B S T R A C T

This study analyzes efforts to reduce the defect rate at a fertilizer factory in Gresik Regency, a company that produces agricultural fertilizers, by implementing the Six Sigma method. The main problem faced by the company is the high level of product defects caused by human factors, methods, machines, and materials, which have an impact on fertilizer quality and production efficiency. This study uses a qualitative approach with the DMAIC (Define, Measure, Analyze, Improve, and Control) method to identify the main causes of defects and formulate improvement strategies. Data were collected through direct observation, interviews with the production and quality control teams, and analysis of documentation related to the level of product defects. The results of the study indicate that the main factors causing defects include lack of operator skills, inconsistency of production procedures, disruption to machines, and instability of raw material quality. By implementing the Six Sigma DMAIC method, the company can reduce the defect rate by improving workforce skills, standardizing work procedures, optimizing machine maintenance, and strict supervision of raw material quality. The implementation of this method is expected to improve the quality of fertilizer products and production efficiency at fertilizer factories in Gresik Regency.

INTRODUCTION

In the current era of Industry 5.0, competition in the manufacturing industry has become highly competitive. Every company strives to dominate the market share. One of the strategies that can be implemented to achieve this is by improving product quality and production capacity while optimizing production costs. To maintain consistency and enhance the quality of products to meet market demands, Quality Control (QC) is essential in every production process. Companies are expected to take strategic steps and design effective strategies, concepts, and techniques to stay ahead in the competition. One of the key approaches is improving product quality (Nurfaizi et al., 2024). Quality control is crucial for companies to detect any deviations that may occur during the production process. One of the measures that can be taken is to prevent or reduce the number of defective products (rejects), ultimately helping to lower production costs and increase productivity (Liga et al., 2024). This method is used to identify issues, assess capabilities, and analyze data. The goal is to enhance processes, eliminate root causes of problems, and ensure long-term control.

Several factors contribute to defective/rejected products in fertilizer companies, including human factors such as lack of knowledge, skill gaps, and inadequate training; method factors such as inefficient work methods; machine factors including suboptimal equipment conditions, such as mixers, conveyors, and granulator machines, as well as inadequate maintenance; environmental factors such as poorly controlled dust levels, humidity, and temperature; and material factors including variations in raw material quality, non-homogeneous material particles, and contamination from foreign substances (Ramdani & Fadilah, 2025).

This approach aims to improve production process performance in fertilizer companies in Gresik, ensuring better control and reducing defect rates (Legimah et al., 2024). This study aims to illustrate the empirical application of the Six Sigma method and the DMAIC approach in minimizing product defects in the production process of a fertilizer company in Gresik. This step is taken to enhance business competitiveness in the global market, which is currently highly dynamic, uncertain, and marked by shifting consumer preferences and rapid technological advancements. The research was conducted at a fertilizer plant in Gresik Regency, a company engaged in agricultural fertilizer production. Several products manufactured include organic fertilizer, NPK fertilizer, granular fertilizer, liquid fertilizer, and compost fertilizer, all located in Gresik Regency, East Java.

Table 1. Fertilizer Defect Data

No	Type of Waste/Reject	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24	Total (kg)	Percentage (%)
1	Imperfect Granules	850	920	875	890	910	930	5,375	30%
2	Unmixed Fertilizer	720	690	710	740	760	750	4,370	24%
3	Clumped Fertilizer	680	660	650	670	690	700	4,050	22%

Source: fertilizer factory in Gresik district (2024)

Based on the data in Table 1, there were a number of fertilizer defects produced in the last six months of 2024 at the fertilizer factory in Gresik district, an agricultural fertilizer processing company. The total defects reached 23,725 kg, with the largest contribution coming from Imperfect Granules (30% or 5,375 kg), while the lowest contribution came from Trial Remainder (5% or 885 kg). The total production output during the period was 3,780,000 kg, which indicates problems in quality control that can affect production efficiency.

This accumulation of defects causes a number of obstacles such as increased waste of raw materials, decreased production efficiency, and potential increases in operational costs. In addition, limited production space can be further disrupted by the accumulation of defective products. Some of the main factors causing defects in fertilizer production include suboptimal machine settings, inappropriate raw material composition, human factors such as lack of workforce training, and process control that still needs to be improved.

Therefore, continuous evaluation and improvement are needed to improve the quality and operational efficiency of the company. According to (Maulidta et al., 2024), Six Sigma is a structured and systematic method for solving quality problems using the DMAIC (Define, Measure, Analyze, Improve, and Control) approach. This method focuses on improving quality with the aim of achieving zero rejects or minimal failure rates Suwarni et al., (2024).

The DMAIC method in Six Sigma is effective for improving production quality. Starting with Define to identify the main problems in fertilizer production, Measure to collect data related to the number of defects and their causes, Analyze to find the root cause of the defects that occur, Improve to design solutions and implement improvements, and Control to ensure that the improvements made continue to run optimally.

This study aims to examine the application of the DMAIC method in improving the quality of the production process at a fertilizer factory in Gresik Regency. It is estimated that by implementing this method, the number of fertilizer defects can be reduced, production efficiency can be increased, and production space can be optimized by minimizing waste of raw materials. With better production quality, companies can reduce production costs and increase competitiveness in the agricultural fertilizer market. In addition, this study is also expected to provide practical recommendations for the fertilizer industry in implementing data-based and sustainable quality control strategies.

RESEARCH METHOD

According to Sugiyono, (2019) the descriptive qualitative research method will discuss the description or phenomenon that occurs. The descriptive method is a study obtained from qualitative data which is then processed and analyzed to obtain conclusions. Qualitative research is obtained based on facts that are in accordance with the field.

Therefore, the researcher uses a qualitative research method with descriptive analysis in order to describe and present an evaluation of the implementation of equipment layout to increase work productivity in a fertilizer company completely, precisely and accurately according to the facts in the field. The focus of this study lies in the company's operational management system and sees the advantages and disadvantages of the fertilizer company's production system. The implementation of this research was carried out in accordance with the company's approval, namely the fertilizer factory in Gresik Regency which is located in Gresik Regency, East Java, Indonesia.

The unit of analysis according to Sugiyono (2022; 292) is that in this unit it is necessary to explain where the place/social situation will be studied. Such as in educational institutions, in companies, in government institutions, in MSMEs. At home, on the street, etc. The unit of analysis used in this study is in the field of fertilizer company production in Gresik district by determining several informants including:

Table 2. Research informants

No	Informant	Department	Years of Service
1	Chief Director	Management	15 years
2	Operations Head	Operations	8 years
3	Admin	Administration	4 years

Researchers chose informants with different positions because each has an important role that complements each other, providing a comprehensive understanding of the production system. The President Director has strategic insight into company management, the Head of Operations is responsible for the effectiveness of the production process, while the Admin has a role in recording and managing operational data. This combination of information allows researchers to gain comprehensive insights from technical, managerial, to administrative aspects, so that the analysis is more comprehensive.

In this study, researchers collected various data from informants. Informants are individuals who have relevant knowledge and information related to the research topic, so that they can provide answers and information needed to answer research questions. Sugiyono (2019) provides the view that informants should be those who have a deep understanding through the enculturation process, so that they not only know something, but also live it. The informants involved in this study included the President Director, Head of Operations, and Admin at a fertilizer factory in Gresik Regency.

The data collection technique in this study used structured interviews, observation, and documentation. Structured interviews are used as a data collection technique when researchers or data collectors already know for sure what information will be obtained. Therefore, in conducting interviews, data collectors have prepared research instruments in the form of written questions whose alternative answers have also been prepared. With this structured interview, data collection can use several interviewers as data collectors. In the observations conducted by researchers in this study, non-participant observation was used. Documents in the form of writing, for example, diaries, life histories, stories, biographies, regulations, policies. Documents in the form of images, for example, photos, motion pictures, sketches, and others. Documents in the form of works, for example, works of art, which can be in the form of pictures, statues, films, and others. Document studies are a complement to the use of observation and interview methods in qualitative research.

Data analysis techniques are the process of systematically searching and organizing through interviews, observations, and documenting data to organize data, choose what is important and what needs to be learned, and facilitate understanding. Namely data collection, data reduction, data presentation, and in the final step, drawing conclusions.

This study uses DMAIC in the validity of research data. Researchers conducted member checks to check the validity of data to employees of fertilizer factories in Gresik Regency. The data provided regarding the operational management system is stated in this study.

RESULTS AND DISCUSSION

In terms of exploration, fertilizer processing companies in Gresik have succeeded in completing the production cycle with high precision and accuracy. However, there are still products that are defective or not good. Factors such as human error, machine maintenance factors, and poor raw materials are the main causes of these defects. Several types of imperfect products, such as fertilizers that are not mixed properly and lumpy fertilizers, often occur due to less than optimal production processes. Therefore, the DMAIC method is applied in this study to improve raw material stock management and reduce the impact of raw material delays on product quality. This method includes the Define stage to identify problems that occur, Measure to measure the impact, Analyze to find the root cause, Improve to design the right solution, and Control to ensure that the implementation of improvements is effective in the long term.

1. **Define**

Currently, fertilizer processing companies in Gresik are facing several critical issues that affect product quality and overall production efficiency. The main issue that needs to be addressed is the high level of defects in fertilizer products, which causes a decrease in quality and an increase in operational costs. Defective products such as fertilizers that are not perfectly mixed or clumped together are a major challenge in maintaining the expected quality standards.

This situation also has an impact on the efficiency of finished product storage space, because products that do not meet standards must be separated and managed specifically. In addition, defective products that cannot be marketed increase production costs and cause waste of resources. The process of sorting and repairing defective products also requires additional time, which can slow down distribution and reduce the company's competitiveness in the market.

Although the production process has followed standard procedures, the high defect rate is still a major challenge that needs to be addressed immediately. This results in decreased customer satisfaction and the potential loss of market share due to products that do not meet expectations. In addition, the increasing number of unsaleable products contributes to increased production costs and inefficiencies in the use of raw materials and labor.

Finally, the company also has difficulty in increasing production output due to the high number of defective products. Low levels of efficiency in production cause backlogs and delays in order fulfillment. Increasing market demand cannot be fully met if the defect rate is still high, so companies need to find effective solutions to improve product quality and reduce the number of defects. The factors causing these defects can come from the quality of raw materials, machine efficiency, operator skills, or constraints in the production process that are not yet fully optimized.

Overall, the high defect rate of fertilizer products is a major challenge that requires immediate attention. Therefore, an in-depth analysis of the root causes of defects is needed in order to formulate appropriate improvement strategies to improve the company's efficiency, quality, and competitiveness in the market.

2. **Measure**

At this stage, the main focus is on collecting relevant data to measure the extent of defects that occur in the fertilizer production process. The data obtained will be the basis for determining the magnitude of the problem and for planning effective improvement steps.

Table 3. Fertilizer defect data

No	Type of Waste / Reject	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24	Total (kg)	Percentage (%)
1	Imperfect Granules	850	920	875	890	910	930	5,375	30%
2	Unmixed Fertilizer	720	690	710	740	760	750	4,370	24%
3	Clumped Fertilizer	680	660	650	670	690	700	4,050	22%
4	Fertilizer Dust	500	520	510	495	505	515	3,045	17%
5	Trial Residue	150	160	155	145	140	135	885	5%
TOTAL WASTE		3,900	3,950	3,900	3,940	4,005	4,030	23,725	-

Source: fertilizer factory in Gresik district (2024)

Based on the data listed in the table above, it can be seen that there are a large number of types of fertilizer rejects or rejects produced in the production process at the fertilizer factory in Gresik district during a six-month period, namely from July to December 2024. This data includes the total weight

of the reject (in kilograms), the contribution of each type of reject to the total reject, and the percentage of rejects compared to the total production output. During the six-month period, the total amount of rejects produced reached 23,725 kilograms. This amount comes from various types of rejects with varying contributions, depending on the source or cause of the reject.

Imperfect granules are the type of reject with the largest contribution, contributing 30% of the total reject, which is around 5,375 kilograms. On the other hand, the reject with the smallest contribution is the remaining trial, with a total of 885 kilograms or 5%. Other types, such as fertilizer dust, which was recorded at 3,045 kilograms or 17%, are also included in the moderate contribution category. Other types of rejects, including unmixed fertilizers and lump fertilizers, account for 24% and 22% of the total rejects, respectively. Fluctuations in the number of rejects can be influenced by variations in production volume, process efficiency, or other technical factors.

Related to the percentage of rejects based on production output, the total production output during the six-month period needs to be further analyzed to determine the impact of rejects on production efficiency and the quality of the fertilizer products produced.

3. Analyze

At this stage, the main objective is to identify the factors that cause high levels of rejects in the fertilizer production process. Based on the data that has been collected, we will conduct a deeper analysis to find the root cause of the problem and the variables that affect production quality.

Table 4. Causes of rejects in the fertilizer production process

No	Factor	Key Point	Actual Condition
1	Man	Operator Skill	Operator skills in raw material mixing are inconsistent.
2	Method	Stock Handling	There is no structured system for raw material mixing.
3	Machine	Machine Downtime	The mixing machine occasionally experiences disruptions during production.
4	Material	Raw Material Quality	Lumpy raw materials are frequently found, hindering the production process.

Sumber : olahan peneliti (2025)

Based on the table above, the main problems in the production process are related to the Man, Method, Machine, and Material factors. In the Man factor, the main problem is the operator's skills in mixing materials that are not evenly distributed, which has an impact on inconsistencies in production quality. On the Method side, the absence of a structured system in ordering raw materials causes delays in stock, which ultimately hinders smooth production.

Meanwhile, in the Machine factor, the mixing machine sometimes experiences problems during the production process, which can slow down the production cycle and reduce operational efficiency. In the Material factor, the quality of raw materials is also a major obstacle, where raw materials are often found to be lumpy, thus inhibiting the mixing process and having an impact on the final product results.

4. **Improve**

At this stage, the steps taken are to provide recommendations to the company to reduce the level of fertilizer product defects caused by human factors, methods, machines, and materials. Based on the previous analysis, the factors that are the main causes of defects in fertilizer factories in Gresik Regency are as follows

a. Human Factor (Man)

The high level of fertilizer product defects is often caused by operator errors in the production process, such as mixing materials that do not meet standards and inaccuracy in operating the machine. To overcome this problem, the proposed solution is to conduct regular training for production operators on stricter operational standards and the application of the Six Sigma method in quality control. This training aims to improve workers' understanding of product quality parameters, reduce human error in the production process, and improve accuracy in machine operation.

The main activity that will be carried out is to compile and implement a periodic training program for all production operators. This training includes basic theory on Six Sigma, quality control methods, and direct practice in operating machines with stricter standards. This program

will be led by the Production Supervisor and Quality Control (QC) Team to ensure that operators have sufficient competence in reducing the level of product defects. With this training, it is hoped that operators can be more careful and efficient in carrying out the production process, so as to reduce the number of defective products produced.

b. Method Factor

One of the main problems that causes the high level of fertilizer product defects is the absence of clear operational standards in the production process and quality control. Errors in mixing materials and inconsistencies in the production stages often result in fertilizer products that do not meet specifications. To overcome this, the proposed solution is to prepare a more detailed Standard Operating Procedure (SOP) based on the Six Sigma DMAIC method.

The main objective of this solution is to ensure that each stage of production is carried out with clear and measurable procedures to reduce variation in production results. Activities carried out include identifying the causes of defects using the Define and Measure stages, analyzing root causes with the Analyze stage, and designing and implementing improvements through the Improve and Control stages. The parties involved in implementing this solution are the Production Team, Quality Control, and Management who are responsible for ensuring that each procedure is carried out according to established standards.

c. Machine Factors

The high level of product defects is also caused by the less than optimal condition of the production machines, such as worn components due to lack of routine maintenance and an imbalance between machine capacity and production demand. In addition, some machines experience inaccuracy in mixing materials, which causes imperfections in fertilizer quality.

To overcome this problem, the proposed solution is to implement a periodic preventive maintenance program to ensure that the machine is always in optimal condition and does not experience disruptions that can increase the defect rate. In addition, an evaluation of the existing machine capacity needs to be carried out to determine whether adjustments or additional machines need to be made to accommodate increasing production demand.

The goal of this solution is to ensure that the machine can operate optimally without experiencing unexpected technical disruptions. Activities carried out include checking the condition of the machine every week, routine lubrication of components that are prone to wear, and monitoring production capacity using the Six Sigma method to ensure that product quality remains consistent. The technician and production teams will work together to develop standard machine maintenance procedures to ensure that each unit continues to function optimally and minimize the risk of defects in the product.

d. Material Factors

Another problem that contributes to the defect rate of fertilizer products is the quality of raw materials that do not always meet specifications, and the absence of an effective checking system to ensure the quality of materials before they are used in production. Some raw materials have certain characteristics that require special storage conditions, but the current storage system does not fully support these needs.

To overcome this problem, the proposed solution is to implement a stricter raw material checking system before the materials are received and used in the production process. This can be done by compiling stricter raw material acceptance standards, such as testing water content, texture, and other parameters relevant to the specifications of fertilizer raw materials. In addition, the stock recording system also needs to be updated so that data on material availability can be accessed in real time and ensure that only quality materials are used in production.

The goal of this solution is to ensure that the raw materials used are always in optimal condition, so as to reduce the defect rate due to materials that do not meet standards. Activities carried out include inspecting raw materials upon arrival, compiling a Six Sigma-based raw material checking SOP, and improving the stock recording system to be more accurate and easily accessible. The parties involved in implementing this solution are the Quality Control (QC) Team which is responsible for checking the quality of raw materials, the Warehouse Team which manages storage, and the Production Team which ensures that the materials used are in accordance with the specified specifications.

5. Control

At the Control stage, to maintain the quality of fertilizer products and ensure that the defect rate remains low, the company will continue to monitor the production process and the final product results. Each stage of production will be closely monitored using a Six Sigma-based quality control system, ensuring that each product produced meets the established standards. A real-time inspection system will be implemented to detect potential quality deviations early on, so that corrective actions can be taken immediately before defective products are produced in large quantities.

In addition, regular training is provided to the production and quality control teams so that they understand new procedures in defect control as well as effective analysis and improvement techniques. A feedback system is also implemented to identify the factors causing defects that still occur, so that any obstacles in the production process can be followed up immediately. All monitoring results will be systematically documented for evaluation and continuous improvement, in order to increase the effectiveness of the implementation of the Six Sigma DMAIC method in reducing the level of defects in fertilizer products at fertilizer factories in Gresik Regency.

CONCLUSION

Based on the analysis and implementation of the Six Sigma method in reducing the defect rate in fertilizer factories in Gresik Regency, the application of this method can help companies improve production quality and operational efficiency. By using the DMAIC (Define, Measure, Analyze, Improve, and Control) approach, companies can identify the main factors that cause product defects and implement appropriate solutions to reduce the defect rate. The results of the study indicate that with improvements in human factors, methods, machines, and materials, companies can significantly improve product quality and reduce the potential for waste due to defective products.

The suggestion from the results of this study is that fertilizer factories in Gresik Regency conduct regular monitoring and evaluation of the implementation of the Six Sigma method, especially in ensuring the sustainability of improvements at each stage of production. In addition, companies are advised to increase training for operators to minimize human error, implement stricter standard operating procedures (SOPs) in handling downtime, and carry out routine machine maintenance to ensure smooth production processes. With a good control system, it is hoped that companies can maintain consistent product quality and increase competitiveness in the market.

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